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SCIENCE AND THE INDUSTRIES

By John J. Carty
Vice President, American Telephone and Telegraph Company

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An Address delivered under the Auspices of the National Research
Council at Washington, D. C., February 6, 1920

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REPRINT AND CIRCULAR SERIES

OF THE

NATIONAL RESEARCH COUNCIL

NUMBER 8

SCIENCE AND THE INDUSTRIES*

BY JOHN J. CARTY

VICE-PRESIDENT, AMERICAN TELEPHONE AND TELEGRAPH COMPANY

Because of the stupendous upheaval of the European War with its startling agencies of destruction—the product of both science and the industries—and because of the deplorable unpreparedness of our own country to defend itself against attack, there began a great awakening of the American people. The awful shock of arms aroused them to the vital importance of the products of science in the national defense. Their minds were startled by warfare combining the scientific dreams of Jules Verne with the horrors of Armageddon. They witnessed as never before the spectacle of men warring with each other upon the earth, and under the earth, and in the air, and on the sea, and down deep in the waters of the ocean itself. Even in the very ether, scientific offensive and defensive measures were carried out in the effort to maintain or destroy communications.

Although peace has not yet come, hostilities have ceased, let us hope forever, and having concluded its work of organizing science for the war, the National Research Council now turns to its even greater purpose of encouraging and organizing scientific research in America for the advancement of scientific knowledge, and for the attainment of those immeasurable advantages which will accrue from the practical application of such knowledge to the affairs of men.

We must preach and we must prove that, great as were the achievements of science in war, they can be made incalculably greater in peace. Scientific research has proved to be an invaluable

* An address delivered under the auspices of the National Research Council at Washington, D. C., February 6, 1920.

aid to military operations in time of war. It must now be established as an essential part of every industry in time of peace.

To carry out its purpose, the Research Council has sought the aid of some of the American corporations which are in sympathy with this movement, a movement which it is hoped will result in the establishment of an industrial research department in each industrial concern large enough to support one, and in cooperative effort among the smaller concerns. The large corporations are being asked to explain the nature of their research organizations, and the advantages which are derived from them. It is believed that in this way those of our manufacturers who are not yet informed will become interested in research methods and organization and results.

The importance of scientific research to our American industries cannot be exaggerated, and while much has already been accomplished, the investigations conducted by the Research Council indicate a state of affairs in this respect far from being reassuring from the standpoint of international competition.

Most of the principal nations of the earth have research councils or their equivalents, and an International Research Council has already been formed. Enough is already known to justify me in saying that unless the manufacturers of the United States establish research departments as integral parts of their own internal organizations, our industries are bound to fall behind those of other countries.

It is in connection with this program of the National Research Council that the American Telephone and Telegraph Company, which I represent, has the honor to make an exhibit showing some of the results of industrial scientific research. Furthermore, this lecture is the first of a series, dealing with various phases of scientific research, which will continue from year to year and which, it is hoped, will frequently be accompanied by important exhibits.

The Department of Development and Research, which is under my charge, was founded about forty years ago to utilize the services of scientific men in developing the telephone art. It has grown from small beginnings with but a few workers, to a great institution employing hundreds of scientists and engineers, who devote themselves exclusively to the discovery and improvement of telephone materials, and methods, and apparatus. It is largely owing to the scientific research conducted in these laboratories that the telephone

achievements and development in America have so greatly exceeded those of other countries.

The original personnel of these laboratories consisted of but two men, Alexander Graham Bell, the inventor of the telephone, and Thomas A. Watson, his associate, who constructed under Bell's direction the first telephone, and who heard through it from the lips of Bell himself the first words transmitted electrically.

At the present time the personnel, which includes graduates of a hundred American colleges and universities, consists of thirteen hundred scientists and engineers who devote their time exclusively to research and development in the telephone art.

On the table before you is one of the first products of these laboratories. It is a model of the first telephone by means of which Bell was able to communicate with Watson, but over a distance not greater than across this room. Starting with such feeble instruments, the scientific personnel of these laboratories—the successors of Bell and Watson—by persistent study, incessant experimentation and the expenditure of immense sums of money, have created an entire new art: inventing, developing and perfecting, making improvements great and small in telephone, transmitter, line, cable, switchboard, and every other piece of apparatus and plant required for the transmission of speech.

As a result of this unceasing organized effort and these cumulative improvements in the art, Dr. Bell was enabled to talk once more to Mr. Watson through this original historic instrument, although they were thousands of miles apart, the one at San Francisco and the other at New York.

These two original telephones have increased marvelously in numbers and efficiency, and the first telephone line of a hundred feet in length has been expanded into a network covering the continent, until the telephone system of the United States alone comprehends thirty-one million miles of wire and thirteen million telephone stations connecting a hundred million people located everywhere throughout the country.

Pressing on to achieve still greater distances, the staff of these laboratories, by utilizing many scientific discoveries, have transmitted the human voice, without the use of wires, from Washington across the North American continent to San Francisco and even far out into the Pacific Ocean to the Hawaiian Islands, where words spoken at Washington were plainly heard. By this same apparatus and by these same scientists intelligible speech was for

the first time transmitted across the Atlantic Ocean from Arlington, Virginia, and heard at Paris.

I like to hope that the further use of the telephone in war may be forever deferred, and to contemplate its future as grand and peaceful. It will transmit speech beyond the vast extent of our own country and ultimately, I believe, to the uttermost ends of the earth, breaking down the barriers to the spoken word and preparing the way for a better understanding among men. It is not distance from one another which has produced differences of language among nations. It is lack of intercommunication. It is the failure of the spoken word to penetrate their boundaries.

I have faith that we shall some day build up a great world telephone system making necessary to all the nations the use of a common language or a common understanding of languages which will join all the peoples of the earth into one brotherhood. I have faith that the time will come, so beautifully described by the poet,

“Wherein each earth-encircling day shall be
A Pentecost of Speech, and men shall hear,
Each in his dearest tongue, his neighbor's voice
Tho' separate by half the globe.”

With the development of electric lights, and electric power, and electric traction, all of which came after the invention of the telephone, industrial scientific research laboratories were founded by some of the larger electrical manufacturing concerns and these have attained a world-wide reputation. While vast sums are spent annually on industrial research in these laboratories, it can be said with authority that they return to the industries, and through the industries to the public, improvements in the art which taken altogether have a value many times greater than the cost of their development. It cannot be too often asserted that money expended in properly directed industrial scientific research is sure to bring to the industries most generous returns. In the present state of the world's development, nothing can do more to advance American industries than the adoption by our manufacturers in general of industrial research conducted on scientific principles. Our industries, our manufacturers, our railroads, our public service corporations should all be impressed with the immense savings and advantages which will come to them and to the public from the establishment within their own organizations of departments devoted to development and research.

So much has already been said and so much remains to be said

urging upon us the importance of scientific research conducted for the sake of utility and for increasing the convenience and comfort of mankind, that there is danger of losing sight of another form of scientific research which has for its primary object none of these things. I refer to pure scientific research conducted for the sake of extending the boundaries of knowledge.

Pure scientific research is conducted with a philosophic purpose, for the discovery of the truth, and for the advancement of learning. The investigators in pure science may be likened to explorers who discover new continents or islands, or hitherto unknown territory. They are continually seeking to push forward the frontiers of knowledge. The work of the pure scientists is conducted without any utilitarian motive, for as Huxley says, "that which stirs their pulses is the love of knowledge and the joy of discovery of the causes of things. . . . the supreme delight of extending the realm of law and order ever farther toward the unattainable goals of the infinitely great and the infinitely small, between which our little race of life is run."

The pure scientists are the advance guard of civilization. By their discoveries, they furnish to the engineer and industrial chemist and other applied scientists the raw material to be elaborated into manifold agencies for the amelioration of the condition of mankind. Unless the work of the pure scientist is continued and pushed forward with ever increasing energy, the achievements of the industrial scientist will diminish and degenerate. Many practical problems now confronting mankind cannot be solved by the industrial scientist alone, but must await further fundamental discoveries and new scientific generalizations.

When considered with reference to a single branch of industry, no particular discovery in pure science appears as a rule to be of appreciable benefit. When, however, the total contributions of pure science are reviewed with regard to the industries as a whole, it is found that they have become of incalculable value through adaptation to practical uses by the industrial scientist, with whom I class the engineer and the industrial chemist.

I do not say this because a new incentive is necessary for the pure scientist, for in him there must be something of the divine spark and for him there is no higher motive than the search for the truth itself. But his motive will be intensified by the knowledge that, when his search is rewarded, there is sure to be found contained



JOSEPH HENRY
1799-1878



MICHAEL FARADAY
1791-1876

in the truth which has been discovered the seeds of future great inventions.

While the discoveries of the pure scientists are of the greatest importance to the higher interests of mankind, the practical benefits flowing from them, though certain, are usually indirect, intangible, or remote. From its very nature pure science cannot support itself. Nevertheless it must be conducted regardless of its lack of pecuniary returns.

Who, therefore, is to support the researches of the pure scientist and who is to furnish him with encouragement and assistance to pursue his self-sacrificing and arduous quest for that truth which is certain, as time goes on, to bring in its train so many blessings to mankind? Who is to furnish the laboratories, the funds for apparatus, for travel, and for foreign study?

Because of the extraordinary practical results which have been attained by scientifically trained men working in industrial laboratories, and because of the restricted conditions under which many scientific investigators in universities are so often compelled to work, it has been suggested that perhaps the theatre of scientific research might be shifted from the universities to the great industrial laboratories which have grown up, or to the even greater ones which the future must bring forth.

But we may dismiss this suggestion as being unworthy. Instead of abdicating in their favor, may not our universities, stimulated by the notable achievements of the industrial laboratories, find a way to advance the conduct of their pure scientific research, the responsibility for which rests so heavily upon them.

Various organizations and institutions, not connected with universities, are also engaged in pure scientific research and they are achieving most remarkable results. They should receive every encouragement and their number should be increased, but a home for pure science must always be found in the university.

In matters of science the function of the university is two-fold—the discovery of the unknown, and the teaching of the known. It is a high function of the universities to make advances in pure science, to test reported new scientific discoveries and to place upon those which are found to be true the stamp of their approval. In this way they can determine what shall be taught as scientific truth to those who, relying upon their authority, come to them for knowledge and believe what they teach.

In my Presidential address before the American Institute of Electrical Engineers delivered at Cleveland in 1916, speaking as a representative of engineering and industrial research, I testified to the great value of pure scientific research in universities, and ventured to suggest to the university authorities that they consider the immense debt which engineering, the industries, transportation, communications and commerce owe to them and to pure science. I expressed the hope that the importance of pure scientific research would be more fully appreciated, both within the university and without, since with that appreciation there would come the sympathy and generous financial support so much needed for the advancement of pure scientific research in America.

The time has now come when the universities, aroused by the experience of the war to the ever-increasing importance of science in the public welfare, are striving as never before to fulfill their function of promoting new scientific discoveries. They are asking where they are to obtain the necessary money, particularly when it is impossible for them to maintain adequately the staffs required for teaching those scientific truths which have already been discovered. So great has been the economic disorder created by the war that many of the scientific teachers and others in the universities are compelled to seek other occupations in order that they may support their families. A critical situation confronts our institutions of learning, and unless we come to their rescue, our progress in science will suffer. For the necessary pecuniary aid we must appeal to those generous and public-spirited men and women who desire to dispose of their wealth in a manner best calculated to advance the welfare of mankind, and we must also appeal to the industries themselves which owe such a heavy debt to science.

It is certain that contributions by our manufacturers and by the industrial corporations generally to pure scientific research will in the long run bring manifold returns to them and to the public whom they serve. These returns will come through the medium of industrial research conducted in the rich territory discovered by the scientific investigators of the universities and the other institutions devoted to the cause of science.

In England during the last century Michael Faraday, one of the greatest workers in pure science, discovered the principle of the dynamo-electric machine. Independently of him, and at about the same time, the same principle was discovered by Joseph Henry,

teacher at the Albany Academy, professor at Princeton, the first Secretary of the Smithsonian Institution, and President of the National Academy of Sciences. No controversy arose between Faraday and Henry as to the credit for the discovery, but with that generosity of spirit which characterized them both, each gave a full measure of credit to the other. Indeed, this discovery tended to form a bond of union and became the source of a permanent friendship between them. By agreement among the scientists of all the nations, one of the fundamental electrical units is called the "farad," in honor of Faraday, and another is called the "henry" in honor of Henry. Both of these men devoted their lives to the discovery of new scientific truths, and to the teaching of science.

To them, as to all workers in pure science, "What use is it?" is not the vital question, but rather, "What message does it bring? What truth does it reveal? What law does it establish?"

An experiment in science is but a question put to nature. She will answer truthfully every question that we ask. She will make known to us all her secrets if we have but the skill properly to frame our questions and the wit to appreciate the answers.

An English statesman before whom Faraday performed his fundamental experiment in electromagnetism asked the forbidden question "What use is it?" Faraday replied, "Some day it may be developed so that you can tax it."

Faraday was a good prophet, for upon his fundamental discovery and that of Henry, if I may but include one or two others of a similar fundamental character, there has been erected the entire art of electrical engineering, as it exists throughout the world to-day. Truly this discovery has been developed. To-day mankind is in possession of electrical property valued at twenty billions of dollars and evidence is not lacking that other statesmen besides Faraday's are busy taxing it.

It is my great privilege to have here the identical apparatus employed by Henry, and with this to perform before you to-night the experiment illustrating the fundamental principle in electromagnetism discovered by Faraday and Henry. In this experiment, an electromagnet (see Fig. 1) is made to generate a current of electricity in a coil of wire, as is proven by the deflection of the galvanometer (see Fig. 2). The principle thus discovered is the fundamental one upon which all dynamo-electric machines are built.

The coils of these magnets and this galvanometer were



FIG. 1

The electromagnet with which Henry discovered the induction of currents



FIG. 2
Galvanometer used by Henry at the time he made his discovery of the induction of currents

wound by Henry himself. Even the very wire was insulated with his own hands. Insulated electrical wire, which now seems so common to us that we may perhaps fancy it has always existed, was not an article of manufacture in Henry's time. In fact, it appears that to Henry belongs the credit of having first thought of applying an insulated covering to the wire used for winding electromagnets. Earlier electromagnets had all consisted of a varnished iron core wound about with a few turns of bare wire. Electromagnets with many turns of insulated wire, such as are used in every telephone and telegraph instrument and form part of every dynamo and motor, were first devised and their superiority demonstrated to the scientific world by Joseph Henry.

These historic relics are valued possessions of Princeton University, where for years they have been carefully guarded by Henry's scientific successors. Because of their very great desire to assist the Research Council in its work, the authorities of the University have generously permitted me to bring this apparatus to Washington to perform this experiment before you.

At the time this experiment in natural philosophy was performed by Henry, no one could dream of the wonderful possibilities which it was destined to open to us. The value of this discovery is not to be measured merely by the billions of dollars worth of electrical property which it has made possible. This property has now become such a fundamental part of the mechanism of modern civilization that, if it were suddenly withdrawn from use, the world's industries would become deranged, its communications paralyzed, and transportation would become so disorganized that millions would starve and disorder inconceivable supervene.

That such remarkable results should have followed from this simple experiment conducted by a philosopher seeking only for the truth, surely no one could have foretold. For any practical purpose these old magnets never had a value greater than so much junk, but in the hands of the philosopher they have brought endless advantages which will continue to accrue to the benefit of mankind as long as civilization endures.

In order to encourage those engaged in the industries and in the practical arts and in commerce to make contributions to the support of scientific discovery in the universities and other institutions, and more particularly in order to justify them from a business standpoint in so doing, it is necessary to demonstrate the pecuniary value of

science. I have endeavored to combat the unappreciative views so often held concerning pure science in the universities, and at the same time I have urged the great practical usefulness and profit to be derived from scientific research conducted within the industries. Above all it has been my purpose to show that our future progress in the industries, in commerce, in medicine and in surgery, and in all the practical arts and sciences depends upon fundamental discoveries yet to be made by workers in pure science in our universities and other scientific institutions.

For many years friends of the Albany Academy have tried in vain to raise the few thousand dollars necessary to erect at Albany, where Henry did his early work, a monument to his memory. Once the American people have been made to understand the marvelous contribution which their scientist made to human welfare, their sense of duty and their unfailing generosity will stir them to action. Then, I am sure, they will erect a worthy memorial through which American art will express to American science the gratitude of our people for the discoveries of Henry.

Also, through their generosity, through their gratitude and their feeling of enlightened self-interest, they will relieve the necessities of Princeton, which lacks only pecuniary aid to enable the successors of Joseph Henry there, to carry out in a worthy manner the high traditions which he established at that university.

Even at the Smithsonian, where Henry its first Secretary labored so successfully, many of the wonderful scientific projects of his distinguished successor, Dr. Walcott, are sadly impeded for lack of funds. In this case also, when the truth is known, I am sure that the generosity of our people will not fail.

For these institutions, forever associated with the name of our great American scientist, and for all the universities and other organizations devoted to science, these old magnets wound by the patient hands of Henry himself, have come to speak. Here at the Smithsonian, in the capital of the Nation, the scene of his many triumphs, these venerable relics speak to the American people and plead the cause of science.

The message which they bear expresses much more than the indebtedness of the electrical industry to Henry and Faraday, vast though that is; it expresses the debt of every industry to all laborers in scientific fields. Every age and nation has had its Henrys and

its Faradays who have devoted themselves to the quest for truth; and the fruits of their endeavors when called to testify, could speak as eloquently as these old magnets of the immense practical benefits accruing to the world from what have often seemed to the uninitiated to be trivial scientific investigations.

If it were attempted to appraise the value of science in dollars or to express it in amounts of taxable property, the figures would be inconceivably large. But science can best be measured in terms of human achievement, the mastery of the forces of nature, the elimination of poverty and disease, the prolongation of life, the advancement of learning, the growth of right living and sound thinking, and of good understanding among men.

I have now a message to deliver. Filled with courage and promise and hope, it is addressed to all of those who labor and are burdened with toil. It tells them that the possibilities of science are boundless and that the resources of nature are without number. They are asked no longer to interpret life as a struggle among men for a limited store, where one man's gain must be another man's loss. They are bidden to pay heed to the voice of the scientist and under his leadership join with their fellowmen, all working together in controlling and utilizing the bountiful forces of nature.

They are told that they are pioneers in a new land. They are asked to endure the temporary hardships of the present day as did the early settlers in our own country, who were buoyed up with that vision of vast natural resources which unfolded itself before their eyes. They are told to look about them through the eyes of modern science and they will see that they too are pioneers, and in a world of wonders filled with boundless promise which will be realized by their children and their children's children and all of their generations in increasing measure.

Great as are the scientific accomplishments of our day, they are small indeed compared to the possibilities of the future with which Nature awaits the call of the scientist. Two centuries ago, Sir Isaac Newton, the discoverer of the law of gravitation, who ranks perhaps as the foremost scientist the world has had, expressed his faith in the infinite possibilities of science in the following words:

"I seem to have been only like a boy playing on the seashore, and directing myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

All the wonderful scientific developments since the time of Newton so strikingly confirm the vision of the great philosopher expressed in the words just quoted, that I can predict with a feeling of certainty that the discoveries of the future, if science is properly supported, will be enormously great in comparison to those of our own time. I believe, indeed, that they will be so great that the people of that coming day will look back upon our knowledge of the forces of Nature as we now look back upon that of the North American Indian who, cold and shivering, was ignorant of the coal at his feet with its stores of warmth and power.

For all of the benefits which she has conferred upon us, science asks only that we provide her faithful workers with an opportunity to multiply their efforts in our behalf. Pointing to the past, she holds forth with certainty the promise of further great truths. She tells us that from these truths the engineers and chemists, the physicians and surgeons, the agriculturists and all the other applied scientists trained in our universities, will develop without number marvelous new agencies for the comfort and convenience of man and for the alleviation of human suffering.



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